Scattering and absorption of light by turbid materials, especially dental enamel.

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SUMMARY

The number of people suffering from caries is large; the expenses in dental care are high. Therefore it is comprehensible that much research is done to prevent caries and, if it occurs, to repair the teeth in a natural way (to heal them). To do so a method is required to measure regularly and non-destructively the progress or healing of a carious spot in enamel. The methods used up to now are destructive (like probing) or may not be applied regularly (radiographic methods). For this purpose optical methods have been researched.

The crowns of our teeth are covered with enamel, which consists mainly of apatite crystallites organized in rod-like structures, the prisms. Sound enamel is a rather translucent material. In a cariogenic attack the crystallites are partly dissolved, resulting in opaque regions in the enamel, the so called white spots. On this phenomenon the optical method is based.

So far optical properties of turbid materials, like enamel, were determined by measuring the reflection and transmission of a thin slab of the material. Such a method is not suitable for measurements on whole enamel. So an optical method had to be developed which is based only on reflection measurements of whole enamel.

The aim of this investigation is to develop a method to measure the reflection of visible light in such a way that the results indicate structural changes in dental enamel like those caused by a cariogenic attack.

The structure of enamel as well as structural changes caused by caries are described in chapter 1.

In chapter 2 an available optical method using coherent light has been applied to determine the surface roughness of sound and deminerelized,enamel. The surface roughness is affected only slightly by the

demineralizing process. So changes in the surface roughness due to demineralization have not to be taken into account if we determine the optical properties of bulk enamel.

The relation between light scattering by enamel and its structures is treated in chapter 3. Light scattering by dental enamel is described by a model which includes both crystallite and prism scattering. The model is based on independent data of enamel. The values of the scattering coefficients of wet bovine and human enamel fit well to experimental results. The model explains also the opacity of carious enamel with respect to sound enamel.

The chapters 4 and 5 contain a description of the measuring method to determine the scattering and absorption coefficients from reflection measurements. A small beam of monochromatic light (wavelength between 400 and 700 nm) incident perpendicularly upon the surface of a sample is scattered in the sample; the reflection is measured as a function of the distance to the incident beam, yielding a reflection curve. Two theoretical approaches - the radiative transport equation in the diffusion approximation and the Monte Carlo method - have been used to calculate the reflection curves at given values of the scattering and absorption coefficients. By comparing the experimental curve to the calculated ones the scattering and absorption coefficients of the sample under study are found. Calibration measurements show that the measuring method is reliable. The total error in the measuring results may be 30% at most. More accurate theoretical calculations by consuming more computer-time and more precise measurements by measuring the incident light using a better measuring arrangement will reduce this error.

In chapter 6 the application of the above-mentioned method to sound and demineralized enamel is described. The changes in the scattering coefficient due to demineralization prove to be measurable. The absorption coefficients are too small to be measured. The latter problem may be solved by extending the measuring method to wavelenghts of about 300 nm. Also changes in the scattering coefficient due to demineralization are larger at 300 nm.

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Summarizing, in this research a measuring method was developed to determine the scattering and absorption coefficients of turbid bulk materials, like dental enamel. The relation between changes in the scattering coefficient of enamel and its structural changes has been clarified. It is a promising way to determine structural changes of enamel due to demineralization in vivo.